

# Challenges and Strategies in Pediatric Critical Care: Insights From Low-Resource Settings

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## Abstract

**Background.** Pediatric critical care in low-resource settings faces challenges like inadequate infrastructure, limited personnel, financial constraints, and cultural considerations, leading to poor outcomes for critically ill children. **Methods.** This review synthesizes information from 2 articles on pediatric intensive care units (PICUs) in low- and middle-income countries (LMICs). It identifies challenges such as high care costs, cultural preferences, and resource allocation issues. **Results.** Challenges include the financial burden of care, limited resources, and the need for external funding. Family preferences impact healthcare decisions, leading to ethical dilemmas. Resource allocation issues affect patient outcomes, including delayed diagnoses and high mortality rates. **Conclusion.** Addressing these challenges requires a multifaceted approach involving governments, healthcare providers, and international stakeholders. Standardizing care, investing in infrastructure and training, and promoting collaboration are essential to improving pediatric critical care and ensuring equitable access.

## Keywords

pediatric critical care, low-resource settings, challenges, strategies, outcomes, infrastructure, training

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## Introduction

For critically ill children, access to specialized care can mean the difference between life and death. Pediatric critical care units (PICUs) provide a lifeline, offering comprehensive monitoring, advanced interventions, and family-centered support. These specialized units have revolutionized pediatric care in high-income countries (HICs), dramatically improving patient outcomes. However, this progress has not reached all corners of the globe. Due to many challenges, low- and middle-income countries (LMICs) face a stark disparity in PICU access. This disparity translates into a grim reality: nearly 90% of deaths under 5 occur in LMICs, highlighting the urgent need for improved pediatric critical care services.<sup>1</sup> The history of PICUs is relatively young, tracing back to the mid-1900s polio pandemic, which necessitated the creation of intensive care units (ICUs) for critically ill patients.<sup>1</sup> Recognizing the distinct needs of children, pediatric critical care emerged as a separate specialty. The earliest PICUs commenced operation in

Sweden sometime in 1955, marking the beginning of an era focused on specialized care, technological advancements, and interdisciplinary collaboration.<sup>2,3</sup> Today, PICUs in HICs are well-equipped with cutting-edge technology, staffed with highly trained professionals, and offer services tailored to children's unique physiological and developmental needs.<sup>3–5</sup> Family-centered care is a cornerstone of modern PICUs, recognizing parents' crucial role in decision-making and emotional

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support for their children.<sup>4</sup> However, this model of care often remains elusive in LMICs.

## Literature Review

The stark contrast between PICUs in HICs and LMICs lies primarily in resource limitations. LMICs often lack the infrastructure to establish and maintain robust critical care services.<sup>6,7</sup> This lack includes insufficiently trained healthcare professionals, particularly specialists like pediatric intensivists and critical care nurses. Additionally, essential medications and life-saving equipment are frequently in short supply. The absence of functional ICUs and limited access to crucial monitoring equipment further hinder the ability to provide adequate care for critically ill children in LMICs.<sup>8-11</sup> These resource limitations have a dire impact on patient outcomes. Studies reveal significantly higher mortality rates in children receiving critical care in LMICs compared to those in HICs.<sup>10,11</sup> This disparity stems from the lack of advanced interventions and the inability to provide primary supportive care, such as fluid resuscitation and respiratory support. The burden of disease in LMICs also plays a role. While HICs may focus on complications from chronic illnesses or surgeries in PICUs, LMICs often grapple with a different profile of critically ill children. Infectious diseases like malaria, pneumonia, and diarrhea, along with complications from malnutrition, are more prevalent in these settings.<sup>8,9</sup>

## Unique Contributions and Proposed Solutions

Based on our analysis, despite these significant challenges, hope persists. Researchers and healthcare providers are actively exploring strategies to improve pediatric critical care in LMICs. Our proposed approach includes prioritizing low-cost, high-impact interventions. This could involve developing protocols emphasizing primary supportive care and utilizing medications with proven effectiveness in resource-limited settings. Additionally, we recommend training and education of local healthcare providers as crucial steps for building the capacity to deliver high-quality care within their resource constraints.<sup>12</sup> Collaboration between HICs and LMICs offers another promising avenue for progress. Our recommendations suggest that knowledge sharing, resource allocation partnerships, and technology transfer can empower LMICs to develop sustainable solutions for pediatric critical care. We also propose innovation as a key factor in this progress. The development of low-cost technologies and adaptations of existing protocols designed explicitly for resource-limited

settings can significantly improve accessibility and effectiveness of care. This narrative review not only explores these challenges and strategies but also advocates for targeted interventions and resource allocation.

## Methodology

We meticulously searched databases like PubMed and Scopus using relevant keywords and Medical Subject Headings (MeSH) terms such as “pediatric intensive care unit,” “low-resource settings,” and “LMICs to find studies on pediatric intensive care unit (PICU) services in low-resource settings.” Focusing on English-language publications, we included articles covering PICU infrastructure, staffing, equipment, patient demographics, clinical outcomes, challenges, and innovations. We excluded those unrelated to PICU services or focusing solely on high-income settings. Data extraction concentrated on critical elements such as infrastructure, staffing levels, equipment availability, patient demographics, clinical outcomes, challenges, and innovations. A total of 40 relevant articles were selected. Our review discussed the current state of PICU services in low-resource settings, exploring factors influencing service delivery and potential enhancement strategies. We synthesized our findings to provide a comprehensive assessment of PICU services, considering disparities in service delivery, access obstacles, and innovative approaches to overcoming resource limitations.

## Historical Context

### *Evolution of Picus in Low-Resource Settings*

In high-income countries (HICs) in the 1950s and low-middle-income countries (LMICs) circa 1965, the concept of “intensive care units,” or ICUs, initially emerged. In LMICs, the PICU’s development history is not as thoroughly recorded. By 2015, they predicted a two-thirds decrease in childhood mortality for children under 5.<sup>9</sup> The gap between HICs and LMICs has grown in critical care. PICUs in LMICs are not secure in their current configuration. Both the high burden of pediatric mortality and the significant unrecorded essential burden of care illness persist.

Childhood mortality can be linked to the “three delays” model, which was initially used to explain and identify factors contributing to maternal deaths. The 3 delays are as follows: (1) taking longer to seek care, (2) taking longer to get to the suitable facility, and (3) taking longer to receive care at the facility.

The World Health Organization (WHO) created the Emergency Triage, Assessment, and Treatment (ETAT) to enhance triage and emergency care after learning that

response times had an impact on hospital morbidity rates.<sup>13</sup> Even with the best intentions, there is always room for improvement regarding swift intervention.

### **Key Milestones and Challenges**

Within any LMIC, there are notable differences in the capabilities of pediatric critical care. Certain regions are equally equipped to deliver essential pediatric healthcare in high-income communities. However, most LMIC hospitals require a dedicated pediatric intensive care unit (PICU) with staff trained in pediatric critical care, sufficient nurse-to-patient ratios, equipment, and continuous monitoring capabilities.<sup>9</sup> Because critical care is easily accessed and funded in HICs, it is thriving there. The majority of LMICs lack staffing for these units, certification processes to permit workers to work in PICUs, and pediatric programs of care that are essential for healthcare providers.<sup>9</sup>

The establishment of critical care nursing is fraught with difficulties. Among them are the hospital and nursing administration's lack of comprehension of the role of nurses in critical care; (2) the lack of funding for specialized training or extra pay to promote retention; (3) sufficient staffing for nurse-to-patient ratios; (4) the traditional roles of nurses; (5) the practice of allowing fully trained nurses to stay in the PICU without being re-assigned; and (6) the preference for seasoned pediatric nurses to act as preceptors and mentors to newly hired personnel.<sup>9</sup> Funding is the underlying similarity among all of these restrictions.

Numerous conditions can be treated quickly to reduce the disease burden in low- and middle-income countries. Some claim that there is no such thing as a pediatric emergency and that critical care services don't have to be very costly or reliant on sophisticated technology. Funding and resources for these initiatives could be redirected to address more public health issues.<sup>9</sup>

### **Impact of Socio-Economic Factors on PICU Development**

The quality of pediatric critical care in HIC and LIC countries is rapidly diverging over time. Forty-two of the world's poorest nations are home to nearly 90% of children with mortality rates under the age of 5.<sup>9</sup> Research has shown that people with lower socioeconomic status are more likely than people with higher incomes to experience higher rates of hospital mortality, PICU admission, and worse functional outcomes.<sup>14,15</sup> As a result, routine child screening is more important to identify the connection between pediatric critical illnesses and social determinants of health. It might result in fewer PICU admissions, shorter hospital stays, and lower morbidity

rates overall. In the past, pediatric critical care was thought too costly or immoral to offer in areas with limited resources.<sup>16</sup> Poverty raises stress levels, exposes children to more unfavorable environments, and limits their access to resources that support their health.

### **Disease Burden**

#### **Common Pediatric Critical Illness in Low-Resource Settings**

According to the WHO, acute pediatric critical illnesses are "any severe problem with the airway, breathing, or circulation, or acute deterioration of conscious state."<sup>16</sup> The most common cause of child morbidity rates is infectious diseases, which are responsible for over 6 million deaths each year in children under the age of 5.<sup>17</sup> All of these deaths are preventable. The most prevalent diseases in low-resource settings are diarrhea, malaria, sepsis, and respiratory infections.

#### **Epidemiological Trends and Patterns**

Recent studies have focused on individual illnesses. The PARDIE study findings revealed that pediatric acute respiratory distress syndrome (PARDS) had a prevalence of 3.2% among children admitted to 145 PICUs across 27 countries, with an associated mortality rate of 17%.<sup>17</sup> The Sepsis Prevalence, Outcomes, and Therapies (SPROUT) study concluded that pediatric sepsis was 8.2%, with a mortality of 25% across 128 PICUs across 26 countries.<sup>17</sup> The mortality rates of lower respiratory infections have continued to decline with increased access to care and the availability of antibiotics. Still, they remain the second most frequent cause of mortality among children.<sup>18</sup>

Malaria is responsible for 58% of deaths in 20% of the world's population. The disparity in distribution is higher than any other disease in the world.<sup>18</sup> Oral rehydration therapy has decreased acute diarrhea mortality rates over the past 3 decades. Infectious diarrhea continues to kill approximately 1.4 to 2.5 million children annually. Rates are expected to reduce with improved coverage and dosage of oral hydration therapy.

Mortality rates are influenced by the developmental and economic status of regions and nations, with intersecting risk factors like poverty, inadequate nutrition, substandard sanitation, contaminated water sources, and limited educational opportunities.<sup>18</sup>

#### **Challenges in Early Diagnosis and Intervention**

Most of the prevalent diseases within the pediatric population are preventable through early detection and

treatment. However, patients are seen in an outpatient setting or the ward when they enter the hospital. No formal triage system is implemented; physicians see patients as they arrive. These delays are crucial for the reversal of many diseases. Reviews done by Alali et al<sup>19</sup> observed that the transfer process takes roughly 7 hours. When a critically ill patient is identified, there are already delays in transportation and treatment.<sup>20</sup> There is not enough staff or trained personnel to aid in early detection or rapid access to resources to intervene.

Implementing intensive care services is particularly cost-intensive in low-income countries, where the average health expenditure is approximately \$20 per person yearly.<sup>20</sup> However, the availability of simple critical care interventions can dramatically improve patient outcomes, such as supplemental oxygen, oximetry monitoring, etc.<sup>21</sup> However, it is up to the hospital to be more cost-effective in terms of improvements in quality and efficiency in facilities as well as resource allocation.

## Current Infrastructure

### Overview of PICU Facilities in Low-Resource Settings

The majority of childhood deaths worldwide are attributed to infectious diseases such as pneumonia, diarrhea, and malaria, with severe acute malnutrition exacerbating the consequences of these avoidable illnesses. The burden of pediatric mortality persists in low-resource settings.<sup>9,22</sup> Many fundamental problems arise when discussing existing infrastructure in low-resource settings; issues arise systematically with a scarcity of specialized and dedicated Children's Hospitals with available multidisciplinary subspecialties, even though debated in reported numbers- are significant. A sizable number of low- and middle-income countries also suffer at the level of the emergency department as a result of insufficient staffing accompanied by a high volume of patients, leading to a worsening of pediatric mortality.<sup>23</sup>

These issues and the underreported incidence and prevalence of pediatric acute critical diseases compound the urgent need to underline the provision of Pediatric Critical Care services that are cost-effective, timely, and use evidence-based standardized guidelines.<sup>21</sup> Despite an increased movement for researchers from low-resource settings to extrapolate data, provide organizational frameworks for addressing gaps in delivering healthcare, and produce studies that challenge PICU practices globally,<sup>24</sup> there needs to be an acceleration in bridging existing gaps between high-resource and low-resource countries in providing quality critical care to pediatric patients.

### Bed Capacity and Occupancy Rates

The definition of an ICU bed can be determined by individual hospital practices, defined mainly as a contextual space with technological capabilities above the average inpatient ward space, a workforce to provide intensive care, and a space for escalation and support to carry out quality improvement avenues.<sup>25</sup> Tripathi et al conducted a survey in 2015 distributed globally across 39 low-middle-income countries to evaluate resources between high-income countries and their counterparts. They found that the number of PICU beds was comparable between LMIC and developed countries.<sup>25</sup> Borrowing from Kaur et al's<sup>25</sup> research, "An overview of pediatric critical care in resource-limited settings," they correctly cited a study from Pakistan, where despite the availability of PICU beds, the average number of beds is smaller than average.

Fundamentally, scarce data highlights the actual cost of a PICU bed in LMICs, while a study describing cost analysis from a LMIC perspective concluded that the cost of ICU care compared with developed nations is much less.<sup>25</sup> The average annual healthcare spending per population unit proportionately across LMICs is 5% of that of higher-income countries.<sup>26</sup>

An assumption can be made that the lack of cost-effective equipment and interventions can incentivize a call to action to support more LMICs with adequate funds to close the gap.

Most low-income countries do not have enough national ICU bed data, so an exact estimation cannot be made. Still, an estimate can be derived from a similar systematic review study. They concluded that for every 1000 hospital beds, there are only 15 adult and pediatric critical care beds, with the average ICU size containing 8 beds.<sup>27</sup> Compared to high-income countries, a cap of 30 ICU beds per 100 000 people is the norm, limited data shows 0.1 to 2.5 ICU beds per 100 000 in low-middle-income countries.<sup>26</sup>

### Availability of Essential Equipment & Technology

There is an underestimation of the need for timely, cost-effective, and sustainable equipment in resource-constrained settings. It is one of the most important reasons for the disparity in mortality outcomes between high- and low-resource settings. Most equipment available in LMIC nations' PICU settings either need the technological human resources to calibrate and maintain them or are donated equipment with equipment that must be included.<sup>28</sup>

Generally, ICU equipment was found to be more challenging to access in LMICs,<sup>29</sup> so there is a call for cheaper,

more sustainable solutions, such as using plastic containers for holding water as spacers for inhaler therapy or NG tubes and umbilical vein catheters.<sup>9</sup> Additionally, local resources must be considered so low-income countries can start insourcing maintenance and repair of necessary and lifesaving critical care equipment.<sup>9</sup> Despite the presence of adequately trained staff, lifesaving equipment may not necessarily be available.<sup>30</sup>

### **Human Resource & Staffing Challenges**

Evidence dictates that trained intensivists should staff critical care units.<sup>28</sup> Factually, high-resource settings have twice the number of existing pediatricians in intensive care units as low-resource settings.<sup>29</sup> In addition to existing pediatric critical care providers, studies reflect a need for gold-standard training in curricula.<sup>21</sup>

The need to address the lack of specialized pediatricians trained in critical care is crucial, in addition to promoting allied professionals such as respiratory therapists, dietitians, pharmacists, and nutritionists to be trained in pediatric critical care to promote a multi-disciplinary-centered approach.<sup>9</sup> An additional vital role is that nurses should be trained in providing appropriate pediatric essential care services, with a broad recommendation to increase nurse staffing personnel with a minimum of 1 nurse for every 3 to 4 pediatric critical care patients.<sup>9</sup>

## **Quality of Care and Clinical Outcomes**

### **Standards and Guidelines for Pediatric Critical Care in Low-Resource Settings**

Practical guidelines and standards are crucial for delivering high-quality care in pediatric intensive care units, especially in resource-constrained settings. They enable healthcare providers to prioritize interventions, maximize resource usage, and uphold safety and quality standards for critically ill children. However, the biggest challenge is assessing patient cases, mainly regarding non-communicative children. Developing dependable measurement instruments and incorporating them into standardized care practices is crucial for improving assessment and management outcomes.

Different tiers of care can be established to enhance adequate care. Community-based PICUs can offer diverse services, while Tertiary PICUs provide advanced care for patients requiring surgical procedures. Quaternary or specialized PICUs offer regional care to large populations or extensive catchment areas, providing comprehensive care to complex patients and diagnosis-specific care for select patient populations. These

facilities should have readily available resources for high-level surgical or trauma care.

Pediatric care units can implement guidelines for admission, ICU structure, personnel, resources, patient safety, equipment, technology, and discharge criteria. Admission criteria should match the facility's level of care. Specialized treatments can be managed in quaternary or tertiary ICUs. Pediatric intensivists should serve as primary providers with expertise in caring for critically ill children.<sup>6</sup>

### **Challenges in Meeting Quality Benchmarks**

**Cost of patient care in low-income settings.** High-quality critical care in PICUs typically involves well-coordinated systems and advanced medical interventions, which can be financially burdensome, especially in low-income settings.<sup>31</sup> Mechanical ventilation, an everyday necessity in intensive care, adds to the costs. Securing funding from external sources becomes crucial to address this challenge.

**Family and cultural preferences.** Respecting family and cultural beliefs is essential in healthcare delivery. In many countries, decisions regarding critical care, including initiation and discontinuation, are often made by the family rather than the patient. Financial hardships may influence decisions, leading to challenges in continuing or terminating care.<sup>31</sup>

**Resource allocation.** Limited resources, including equipment and personnel, in PICUs of low-income settings necessitate efficient resource allocation to maximize impact and promote equity in access to care. Cost-effectiveness and sustainability are crucial considerations for optimal resource utilization.<sup>31</sup>

### **Impact on Patient Outcomes**

Challenges in low-income settings PICUs affect patient outcomes in various ways, influenced by healthcare access, resource availability, socioeconomic status, and psychosocial factors. Limited published data on pediatric care in these settings highlight issues such as delayed diagnoses and high mortality rates due to resource constraints.<sup>32</sup> Studies reveal that patients admitted to PICUs consume significant resources, with subsequent improvements in survival rates and functional outcomes among prolonged-stay patients.<sup>32</sup> However, severe sepsis or multiorgan failure remains an important complication, affecting nearly 17.9% of patients in low-income pediatric care units.<sup>33</sup> Addressing these challenges necessitates further research, resource

**Table 1.** Recommendations Summary.<sup>6</sup>

Tier	Critical care services
Tier 1: Basic critical care services	Oxygen therapy Patient cohorts Early identification and intervention for patient deterioration
Tier 2: Intermediate critical care services	Enhanced monitoring equipment (eg, pulse oximeters, essential ventilators) Training programs for healthcare providers on pediatric critical care ICU staffing models guarantee swift responses to emergent patient needs, with clearly defined roles Essential ICU personnel and resources encompass nursing staff, respiratory therapists, clinical pharmacists, social workers, child life specialists, and palliative care services Access to transfer and transport programs, with specialized teams for quaternary facilities
Tier 3: Advanced critical care services	Comprehensive PICU facilities with advanced life support equipment Specialized training and continuous professional development for critical care staff Trauma and burn patients benefit from collaborative management by trauma/burn surgeons and PICU teams Night coverage by pediatric intensivists should be easily accessible, particularly in specialized PICUs with in-house critical care fellows Performance improvement and patient safety initiatives, such as academic pursuits and community outreach education, should be integral to quaternary and tertiary PICUs Clear discharge and transfer criteria based on patient physiologic status Discharge planning should involve communication with accepting facilities, primary care physicians, and subspecialists and coordination of outpatient services

allocation, and evidence-based interventions to enhance outcomes for patients and their families in low-income settings.

## Challenges, Future Direction, and Policy Recommendations

Specific recommendations for critical services (Table 1).

### *Persistent Challenges in Pediatric Critical Care*

Persistent challenges in pediatric critical care persist despite efforts to improve facilities in limited-resource settings. Factors such as inadequate medical resources, poor triage and emergency treatment, insufficient personnel, and lack of essential equipment hinder effective care delivery.<sup>9</sup> The absence of regulations and standards exacerbates these challenges, leading to inconsistencies in patient treatments and poor clinical outcomes.<sup>34</sup>

### *Potential Strategies for Improvement*

To address these challenges, standardizing care processes through tailored protocols and procedures is crucial.<sup>35</sup> Additionally, investing in PICU facilities, acquiring essential equipment, strengthening emergency and triage protocols, and improving healthcare infrastructure are necessary steps.<sup>36</sup> Capacity-building through training programs to empower medical professionals and promote the adoption of evidence-based practice and

interdisciplinary collaboration is essential.<sup>9</sup> Collaboration between high-income countries (HICs) and LMICs and sharing effective practices, methods, and resources can significantly improve child critical care globally.<sup>36</sup>

### *Research Priorities and Areas for Further Investigation*

Research priorities include conducting epidemiological studies to understand the frequency of severe illnesses in children in low-income areas and exploring disease incidence, mortality rates, and associated risk factors.<sup>37</sup> Health system strengthening studies are needed to identify structural impediments and enablers of pediatric critical care in low-resource settings.<sup>37</sup> Assessing interventions to enhance pediatric essential care outcomes through scientific research is crucial to determining their impact and potential for replication.<sup>38</sup> Understanding the connection between health equity and social determinants, such as poverty, education, or access to medical services, is vital for identifying health disparities and informing targeted interventions to promote equity in health.<sup>38</sup>

## Conclusion

Providing pediatric intensive care in resource-constrained settings is often met with significant limitations, including inadequate infrastructure, personnel, and financial constraints. Despite efforts to improve PICUs, disparities between HICs and LMICs persist, leading to suboptimal outcomes for critically ill

children. Based on our analysis, standardizing care processes, investing in infrastructure and capacity-building initiatives, fostering collaboration between HICs and LMICs, and prioritizing research on epidemiology, health system strengthening, and intervention effectiveness are crucial for advancing pediatric critical care globally. We conclude that addressing these challenges requires coordinated efforts from governments, healthcare providers, academic institutions, and international stakeholders. Furthermore, our perspective emphasizes the need to prioritize equitable research that moves beyond descriptive studies and concentrates on interventions that enhance patient outcomes, with researchers from LMICs leading and participating in this effort. This strategy guarantees that research appropriately addresses the unique requirements of LMICs and is contextually relevant.

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### Author Contributions

Mohammed Alsabri (MA) and Gbolahan Olatunji (DG) are considered as the first authors and corresponding author proposed the project, contributed to the conception, formulation, drafting of the article, reviewed and revised the manuscript along with (EK, NA, DE, AA, TB, LM) participated in writing and revision the final manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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